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Does Everybody Need Good neighbors?
Labor Mobility Costs, Cities and Matching

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Does Everybody Need Good Neighbors? Labor Mobility Costs, Cities and Matching*

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Abstract

This paper analyzes the role of costly spatial interaction between regional labor markets in the matching process. We adapt Shimer and Smith's (2000) assignment model with search frictions to an economy with two connected regions. We then show that the existence of labor mobility costs will induce only the high-skilled workers in the small town to commute (migrate) to the large city, while low-skilled workers continue to search jobs locally. Since there are fewer workers searching for jobs in the small town, fewer firms enter the region resulting in a decrease in the local contact efficiency for workers. This implies that only high-skilled workers benefit from the proximity to large cities, whereas low-skilled workers in the small town suffer from a deteriorated local contact efficiency. Empirical evidence using Belgian linked employer-employee data is consistent with the implications of the model.

Keywords: Assortative matching; strength of matching; labor mobility costs; selection

JEL Classification: J24; J64; R12; R23

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1 Introduction

This paper shows that in the presence of an increasing returns to scale contact technology and labor mobility costs, the interaction between regional labor markets, in the forms of migration and commuting, improves the match quality of high-skilled workers in the small region, however, it diminishes the match quality of low-skilled workers. The different impacts on high- and low-skilled workers is a key new insight in this paper. To the best of our knowledge, the effect of the spatial interaction between regional labor markets for heterogeneous workers has not been documented in the literature.

The economic space is the outcome of a trade-off between various forms of increasing returns to scale (either internal or external) and different types of mobility costs. Krugman (1980, 1991) emphasizes the interaction of firm-level increasing returns to scale and transport costs, which creates an incentive for agents to locate near the large market and thus produce agglomeration (see Fujita et al., 1999)[1]. In the field of urban economics, a large body of literature has identified a number of sources of the external increasing returns that produce agglomeration, for example, labor market pooling, input sharing and knowledge spillovers, suggested by Marshall (1890) (see review of Duranton and Puga, 2004; Rosenthal and Strange, 2004). One interpretation of labor market pooling is that the larger and thicker labor market can improve the quality of the match between firms and workers (Helsley and Strange, 1990; Wheeler, 2001; Amiti and Pissarides, 2005; Andersson et al., 2007). This line of research incorporates both worker and firm heterogeneity, which is stressed in recent pa-

[1] Krugman (1980) describes the relationship between increasing returns to scale (fixed cost of production) and transport costs as follows: "In a world characterized both by increasing returns and by transportation costs, there will obviously be an incentive to concentrate production of a good near its largest market, even if there is some demand for the good elsewhere. The reason is simply that by concentrating production in one place, one can realize the scale economies, while by locating near the larger market one minimizes transport costs."

pers by Venables (2011) and Ottaviano (2011), and they often assume an increasing returns to scale contact technology between workers and firms. However, the role of labor mobility costs, i.e., commuting cost (migration cost) and lower efficiency of inter-regional job search, has been far less researched. In this paper, we shed light on the interaction between increasing returns to scale in job search and labor mobility costs. More specifically, we introduce labor mobility costs into an assignment model with search frictions, two-sided heterogeneity and free entry of vacancies in a multi-regional setting.

The model that we propose is an extension of Shimer and Smith (2000), which analyze search frictions in an assignment model with heterogeneous workers and firms. The main innovation of our theory is that we introduce the spatial interaction between regional labor markets which is exposed to labor mobility costs into Shimer and Smith (2000). Regions only differ in the size of the labor market, which is treated as exogenous. The two regions are connected to each other by means of commuting and migration. Workers are free to search for jobs in either or both regions and they are subject to two types of labor mobility costs if they search jobs in the other region. First, because of the difficulties that workers face in gathering information about jobs in the other region, an inter-regional job search is less efficient than an intra-regional job search. Second, workers have to pay fixed commuting costs if they accept a job in the other region. Workers optimally search for employment in two regions. The supply of vacancies is determined by the free entry condition. Finally, workers are allowed to migrate across regions in the model, which determines the regional skill distribution.

Under a contact technology which exhibits increasing returns to scale, workers expect to have more contacts with firms per unit of time in larger regions and thus search is more efficient. Given complementarities in production, the benefit of matching with firms with high productivity is greater for high-skilled workers than for low-skilled workers. Fixed costs of migration and commuting ensure that, in the small region only high-skilled workers find it profitable to migrate to the large region and median-skilled workers search jobs only in the large region and commute to work if employment is found. However, low-skilled workers in the small region continue to search jobs locally. Free entry of vacancies implies that more firms will enter the large region and fewer firms will enter the small region, which leads to a decrease in the contact rate for the remaining workers in the small region. Thus, high-skilled workers benefit from the proximity to the large market because of the improved contact efficiency, however, left-behind low-skilled workers lose from the proximity because of the deteriorated contact efficiency in the local region.

Apart from the implications for the effect of spatial interaction between regional labor markets on heterogeneous workers, our model yields implications for regional wage differentials as well as the mechanisms that produce agglomeration. Since the job search is more efficient in the large region, wages are higher in the large region for all worker types, which is consistent with numerous empirical findings of the wage premium in large cities (see for example Glaeser and Mare, 2001; Wheeler, 2001; Gould, 2007; Combes et al., 2008; Glaeser and Resseger, 2010). The wage premium in the large region and labor mobility costs imply that high- (median-) skilled workers migrate (commute) from the small region to the large region, which leads to an increase in the number of firms in the large region and thus to further migration and commuting. This process of circular causality - workers search jobs in the region where firms concentrate, and firms tend to locate in a region with large labor market - leads to a further concentration of economic activity. This mechanism is comparable to the process of circular causality described in Krugman (1991). Consequently, disproportionately more skilled workers tend to cluster in large regions (Bacolod et al., 2008; Venables, 2011).

Our empirical analysis is based on a unique Belgian linked employer-employee dataset provided by the Crossroads Bank for Social Security in Belgium. Our measures of skill and productivity derive directly from wages. The data confirm that the large local labor market improves the quality of match for all worker types, especially for low-skilled workers. However, the large neighboring labor market only improves the quality of match for high-skilled workers but diminishes the quality of match for low-skilled workers.

This paper relates to several strands of literature. First, our model is an extension of Shimer and Smith (2000), which introduce search frictions, see for example Diamond (1982), Mortensen (1982) and Pissarides (1990), in the assignment model with two-sided heterogeneity (for example Becker, 1973). Our findings are also related to the literature on the relation between match quality and size of labor market. For example, assuming that search cost is a decreasing function of the size of the market, Wheeler (2001) shows that the larger labor market increases the strength of sorting. Moreover, we are not the first to study the job search behavior in a multi-regional setting. Coulson et al. (2001) construct a search model involving two regions to analyze spatial mismatch. Gautier and Teulings (2009) develop a search model with costless migration and trade in a multi-regional setting. But the number of workers in a region, which is determined by the stock of real estate, is treated as exogenous in their paper.

The rest of this paper is structured as follows. Section 2 shows the theoretical model and illustrates the equilibrium. Section 3 describes the data used in the analysis and presents some stylized facts. Section 4 provides the empirical strategy, and the results are presented in Section 5. Section 6 concludes.

2 The Model

2.1 General Structure

Figure 1 gives an overview of the general layout of the economy that we consider in this paper. It is a continuous time economy with heterogeneous agents, complementarities in production and search frictions. The economy consists of two regions which differ in the size of labor market and we assume region A is larger than region B, $L_A > L_B$, which is treated as exogenous[2]. Workers and firms can produce only in pair, and they are allocated to each other via a random matching technology. This matching process is time-consuming and all agents are infinitely lived and discount the future at a common rate $r > 0$. Under the contact technology of workers and jobs with increasing returns to scale, workers (jobs) meet more jobs (workers) per unit of time in the larger region which makes workers (jobs) more selective. Workers in each region are free to search for jobs in either or both regions. Inter-regional job search is subject to less efficiency of the contact technology and commuting costs. When a worker meets with a job, she faces a trade off between accepting it or continuing to search for a more suitable job. The optimal strategy is to accept the wage that exceeds a threshold value, which is the reservation wage. For each worker, there is a reservation wage associated with each region reflecting region-specific contact rate and commuting costs. Workers search jobs in the region with the highest associated reservation wage. The number of firms (vacancies) in each region is determined by a free entry condition. In the rest of this paper, firms, jobs and vacancies are used interchangeably.

The two regions are related to each other by (1) inter-regional job search and commuting; (2) labor migration. Both commuting and migration are costly. Workers living in region

[2]This can be extended to n regions.

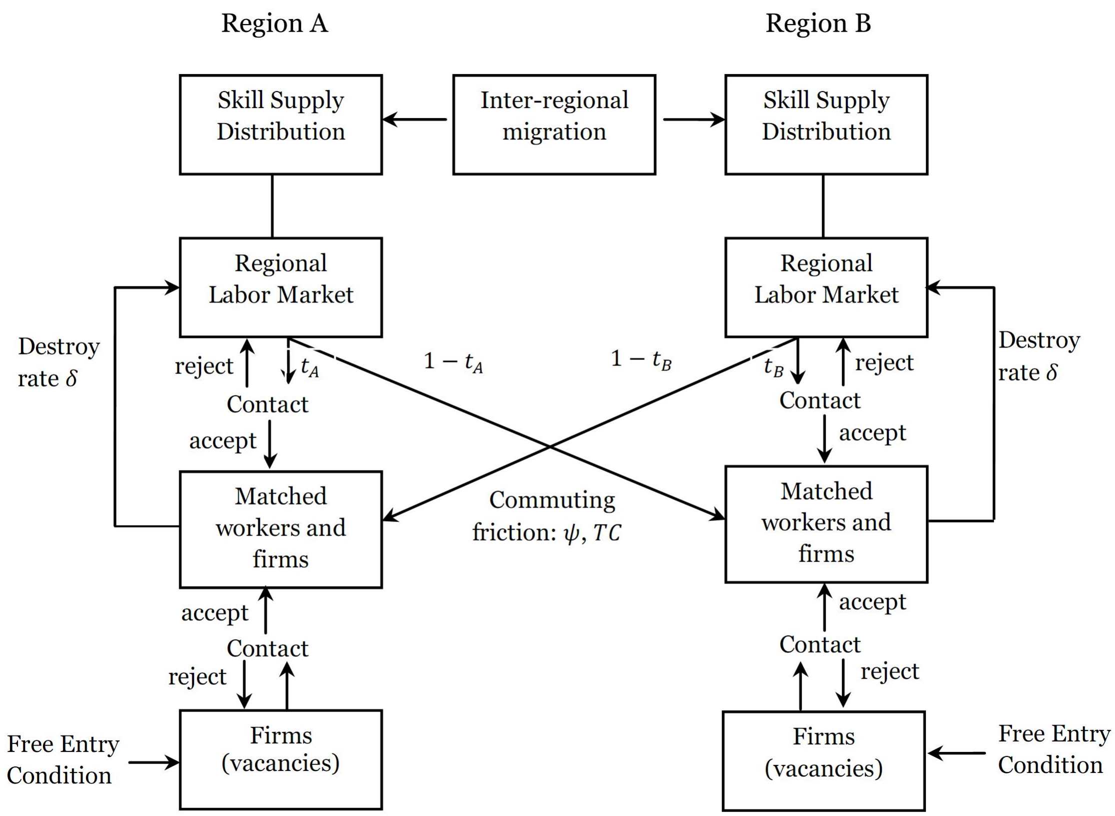

Figure 1: Regional Labor Markets

A have no incentive to search jobs in region B (or migrate to region B), as job search is more efficient in region A. Because of complementarities in production, the benefit from an improved match increases with worker types. Thus only high-skilled workers in region B find it profitable to search jobs in region A and commute if employment is found. Low-skilled workers in region B only search jobs locally.

2.2 Assumptions

2.2.1 Production

There is a continuum of worker types s (skill) supplying one unit of labor and firm types p (productivity) which are observable ex-ante, following log normal distribution.

$$logs \sim N(\mu^s, \sigma^s)$$

$$logp \sim N(\mu^p, \sigma^p)$$

The type density function for workers is $l(s)$. The type density function for firms is $g(p)$. Each firm only has one vacancy to fill by hiring one worker. Entry in the production (job opening) is costly. Each firm learns its productivity p only after making the irreversible investment f_E unit of output required for entry. We model this as a draw from a common distribution. The supply of vacancies in the market is determined by a free entry condition. A worker of type s and a firm of type p produce $f(s,p)$ when matched and nothing otherwise. As in Lu and Mc-Afee (1996) and Teulings and Gautier (2004), we assume that the production function $f(s,p)$ is supermodular with the following functional form[3]:

$$f(s,p) = sp$$

The marginal product of a worker increases the more productive the firm is. It implies that the benefit of matching with firms of high productivity is greater for workers with high skills than for those with low skills. In order to focus on labor markets, we implicitly assume that

[3] $f(s,p)$ is supermodular if $\forall s > s'$ and $\forall p > p'$, the following condition holds: $f(s,p) + f(s',p') > f(s,p') + f(s',p)$. See Milgrom and Roberts (1990) for discussions of supermodularity and forms of complementarities.

goods markets are perfectly competitive.

2.2.2 Job-search technology

Each worker has a unit time endowment and is free to search for jobs in either or both regions. Let $t_i(s)$ and $1-t_i(s)$ denote the time a worker of type s in region i devotes to search jobs in region i and j, respectively.

Contacts are random, i.e., unemployed workers contact vacancies at random. In order to address the contact technology, we first introduce some notations. Let $M(s,p)$ be the total number of contacts between job seekers of type s and vacancies of type p. $u_i(s)$ denotes the density of unemployed workers of type s per unit of labor supply L_i in region i, hence $\frac{u_i(s)}{l(s)}$ is the unemployment rate for workers of type s. υ_i is the total number of vacancies per unit of labor supply, while the total number of vacancies is $\upsilon_i L_i$. Then the density of vacancies of type p per unit of labor supply is $\upsilon_i(p) = \upsilon_i g(p)$. Only firms with vacancies and unemployed workers search. There is no on-the-job search.

Workers in region A can search either in region A with efficiency indicator 1 or in region B with efficiency indicator ψ, $0 \leq \psi \leq 1$. Because the gathering information regarding available job openings is more difficult across regions, inter-regional job search is less efficient than intra-regional job search. Under a quadratic contact technology which exhibits increasing returns to scale, the total numbers of contacts between job seekers of type s and vacancies of type p in region A and B during a given time interval are:

$$\begin{aligned} M_A(s,p) &= \mu\Big\{t_A(s)u_A(s)L_A + \psi[1-t_B(s)]u_B(s)L_B\Big\}\upsilon_A(p)L_A \\ M_B(s,p) &= \mu\Big\{t_B(s)u_B(s)L_B + \psi[1-t_A(s)]u_A(s)L_A\Big\}\upsilon_B(p)L_B \end{aligned} \tag{1}$$

where μ measures the overall efficiency of the contacting process. The term $t_A(s)u_A(s)L_A + \psi[1 - t_B(s)]u_B(s)L_B$ is the effective number of workers searching jobs in region A, namely $t_A(s)u_A(s)L_A$ unemployed workers in region A searching jobs in region A and $[1-t_B(s)]u_B(s)L_B$ unemployed workers in region B searching jobs in region A, which are discounted by a factor ψ due to their lower search efficiency. $v_A(p)L_A$ refers to the number of vacancies with productivity p in region A. The parameter ψ in equation (1) measures the relative efficiency of inter-regional job search relative to intra-regional search: $\psi = 0$ is the case without inter-regional job search; $\psi = 1$ is the case that intra- and inter-regional job search are equally efficient. If job information is assumed to decline with distance from opportunities, relative searching efficiency strongly depends on the distance between two regions, with $\psi'(d) < 0$[4]. The underlying assumption here is that each worker's residence is predetermined and workers search for jobs from a given residential location. In Section 2.5, we will relax this assumption and allow for migration, thus workers are able to choose their region of residence.

Quadratic contact technology, which avoids congestion effects between different worker and job types, has been frequently used in the search literature. Teulings and Gautier (2004) provide a number of motivations to understand why the quadratic technology is the most appropriate assumption in a model with two-sided heterogeneity[5]. The technology refers to the number of potential contacts between workers and firms, but not the number of realized matches. Moreover, workers and firms become more choosy in the large region with greater

[4] Firms place help-wanted signs in their windows or place ads in local newspapers. Thus job seekers living further away have less information on these jobs. Moreover, a large fraction of jobs are found through personal referrals rather than formal contacts (Greenwald, 1986; Montgomery, 1991), which leads to the lower search efficiency of workers living in another region who have less local social networks. Seater (1979) also shows that workers' searching further away from their residence are less productive in their search activities than those who search closer to where they live.

[5] In the case of a contact technology that does not exhibit increasing returns to scale, an increase in the number of unemployed hamburger flippers would impose a congestion on the unemployed rocket engineers looking for appropriate jobs, which is unrealistic.

efficiency of contact process, which partially cancels out the effect at the aggregate level (Petrongolo and Pissarides, 2006). So the assumption of quadratic contact technology does not contradict the empirical findings of constant returns to scale for realized matches at the aggregate level (see Petrongolo and Pissarides, 2001, for a survey).

Given the quadratic contact technology, the implied contact rates $\rho_{s\to p}$ for worker type s to run into job type p (or $\rho_{p\to s}$ for job type p to run into worker type s) are:

$$
\begin{aligned}
\rho_{iis\to p} &= \mu t_i(s)\upsilon_i(p)L_i \\
\rho_{iip\to s} &= \mu t_i(s)u_i(s)L_i \\
\rho_{ijs\to p} &= \mu\psi[1-t_i(s)]\upsilon_j(p)L_j \\
\rho_{ijp\to s} &= \mu\psi[1-t_i(s)]u_i(s)L_i
\end{aligned}
\tag{2}
$$

where the first subscript of ρ denotes the location of workers and the second subscript refers to the location of firms. For example, $\rho_{ABs\to p}$ denotes the contract rate for unemployed workers s in region A to run into the vacancies p in region B. Equation system (2) suggest that the contact rates are increasing in the size of labor market[6].

Following Shimer and Smith (2000), we assume that matches between employers and employees are destroyed randomly at an exogenous rate $\delta > 0$, which is independent of the location. When the match is destroyed, both workers and employers re-enter the pool of searchers.

[6]In other words, workers in the larger region meet more jobs per unit of time.

2.3 Equilibrium Conditions

Each agent maximizes her expected present value of payoffs. A steady-state (pure) strategy for a worker s is a time-invariant set $A(s)$ of firms with whom s is willing to match. The set $\Omega(s) = \{p|s \in A(p)\}$ is an inverse set consisting of firms willing to match with the worker s. A worker s's matching set is $\omega(s) = A(s) \bigcap \Omega(s)$, where a match (s, p) is mutually agreeable if and only if $p \in \omega(s)$. So the matching sets are symmetric, $p \in \omega(s)$ if and only if $s \in \omega(p)$.

In steady state, the flow into the unmatched pool and the flow out must exactly balance for every type of worker. The density of matched (employed) workers in region A is $l_A(s) - u_A(s)$, and the matches exogenously dissolve with a constant flow probability (Poisson rate) δ. The flow of matches created by unmatched workers of type s living in region A is $u_A(s) \int_{\omega_{AA}(s)} \rho_{AAs \to p} dp + u_A(s) \int_{\omega_{AB}(s)} \rho_{ABs \to p} dp$, namely $u_A(s) \int_{\omega_{AA}(s)} \rho_{AAs \to p} dp$ matches in region A and $u_A(s) \int_{\omega_{AB}(s)} \rho_{ABs \to p} dp$ matches in region B. In steady state, for all worker types s in region A, we have:

$$\begin{aligned} \delta(l_A(s) - u_A(s)) &= u_A(s) \int_{\omega_{AA}(s)} \rho_{AAs \to p} dp + u_A(s) \int_{\omega_{AB}(s)} \rho_{ABs \to p} dp \\ &= \mu t_A(s) L_A u_A(s) \int_{\omega_{AA}(s)} \upsilon_A(p) dp + \psi \mu [1 - t_A(s)] L_B u_A(s) \int_{\omega_{AB}(s)} \upsilon_B(p) dp \end{aligned} \tag{3}$$

The left-hand side of equation (3) is the outflow of workers from the matched pool. The right-hand side of equation (3) refers to the inflow of workers that find jobs in region A and region B.

Let $U_i(s)$ denote the expected value of an unemployed worker s in region i, $i = A, B$. Similarly, let $W_{ij}(s|p)$ be the present value for a worker s in region i while matched with a firm p in region j, $i, j = A, B$. And $S_{ij}(s|p) = W_{ij}(s|p) - U_i(s)$ is her personal surplus when matched.

While unmatched, a worker s in region A gets unemployment benefit UB[7], but at flow rate $\mu t_A(s) L_A \int_{\omega_{AA}(s)} \upsilon_A(p)dp$ she meets and matches with some $p \in \omega_{AA}(s)$ in region A and enjoys a gain $S_{AA}(s|p)$, and at flow rate $\psi\mu(1-t_A(s))L_B \int_{\omega_{AB}(s)} \upsilon_B(p)dp$ she meets and matches with some $p \in \omega_{AB}(s)$ in region B and enjoys a gain $S_{AB}(s|p)$. The value of being unmatched for a worker s in region A is generated by the Bellman equation:

$$rU_A(s) = \text{UB} + \max_{t_A(s)\in[0,1]} \Big\{ t_A(s)\mu L_A \int_{\omega_{AA}(s)} S_{AA}(s|p)\upsilon_A(p)dp + [1-t_A(s)]\psi\mu L_B \int_{\omega_{AB}(s)} S_{AB}(s|p)\upsilon_B(p)dp \Big\} \tag{4}$$

Workers use their time endowment optimally to search for employment in two regions. Although unemployed workers are free to use their one unit time endowment to search for employment in either or both regions, obviously, search time is completely specialized, i.e., $t_A(s) \in \{0, 1\}$. In other words, a worker s living in region i only search jobs in region i if the value of being unmatched when searching for employment in region i is greater than or equal to the value of being unmatched when searching for employment in region j.

$$t_A(s) = \begin{cases} 1 & \text{if } \mu L_A \int_{\omega_{AA}(s)} S_{AA}(s|p)\upsilon_A(p)dp \geq \psi\mu L_B \int_{\omega_{AB}(s)} S_{AB}(s|p)\upsilon_B(p)dp \\ 0 & \text{otherwise} \end{cases} \tag{5}$$

The value of a vacancy with productivity p, likewise, can be written as follows:

$$rV_A(p) = \mu L_A \int_{\omega_{AA}(p)} t_A(s) S_{AA}(p|s)u_A(s)ds + \psi\mu L_B \int_{\omega_{BA}(p)} (1-t_B(s))S_{BA}(p|s)u_B(s)ds \tag{6}$$

[7] UB may also reflect the value of leisure and home production.

At flow rate $\mu L_A \int_{\omega_{AA}(p)} t_A(s) u_A(s) ds$ a firm p in region A meets and matches with some $s \in \omega_{AA}(p)$ from region A and enjoys a gain $S_{AA}(p|s)$, and at flow rate $\psi \mu L_B \int_{\omega_{BA}(p)} (1 - t_B(s)) u_B(s) ds$ the firm meets and matches with some $s \in \omega_{BA}(p)$ from region B and enjoys a gain $S_{BA}(p|s)$.

Prior to entry, the expected net value of a vacancy in region A is $V_A - f_E$. If this net value is negative, no firms would enter the market. The expected net value is driven to zero by the unrestricted entry of new vacancies. This yields the equilibrium free entry condition.

$$rV_A = r \int V_A(p) g(p) dp = r f_E \tag{7}$$

While matched, a worker s in region i gets the payoff $\pi_{ij}(s|p)$ when she matched with a firm p in region j and we have the resource constraint $\pi_{ij}(s|p) + \pi_{ij}(p|s) \equiv f(s,p)$. With rate δ, her match is destroyed and she suffers a loss $S_{ij}(s|p)$. Then the value of a match for a worker s in region i with a firm p in region i is:

$$rW_{ii}(s|p) = \pi_{ii}(s|p) - \delta S_{ii}(s|p) \tag{8}$$

Workers living in region i have to pay the commuting cost (transportation cost, commuting time) when they accept a job in region j. So the value of a match for a worker s in region i with a firm p in region j is:

$$rW_{ij}(s|p) = \pi_{ij}(s|p) - TC - \delta S_{ij}(s|p) \tag{9}$$

where TC is the commuting cost a worker has to pay for every period, depending on the distance between two regions, $TC'(d) > 0$. In other words, it is costless for workers to commute within their own labor market, but it is costly to commute from one location to another.

While matched, wages are set by a simple Nash bargaining as in Pissarides (1990) with θ being worker's bargaining power, $0 < \theta < 1$. From the first order condition, we have $(1-\theta)[W_{ij}(s|p) - U_i(s)] = \theta[J_{ij}(p|s) - V_j(p)]$, where $J_{ij}(p|s)$ is the present value for a firm p in region j while matched with a worker s from region i. Using (8), (9) and the resource constraint, we obtain the surplus of workers and firms:

$$\begin{aligned} S_{ii}(s|p) &= \theta\left[\frac{f(s,p) - rU_i(s) - rV_i(p)}{r+\delta}\right] \\ S_{ii}(p|s) &= (1-\theta)\left[\frac{f(s,p) - rU_i(s) - rV_i(p)}{r+\delta}\right] \\ S_{ij}(s|p) &= \theta\left[\frac{f(s,p) - rU_i(s) - rV_j(p) - TC}{r+\delta}\right] \\ S_{ij}(p|s) &= (1-\theta)\left[\frac{f(s,p) - rU_i(s) - rV_j(p) - TC}{r+\delta}\right]. \end{aligned} \tag{10}$$

where $rU_i(s) = w_i(s)$ is the average present value of an unmatched worker s in region i, i.e., reservation wage, $rV_i(p) = w_i(p)$ is the average present value of an unmatched vacancy p in region i. Personal surplus is a share, reflecting her bargaining power, of the excess of matching output over both unmatched values and the commuting cost if it is a cross-regional match. Discount rate accounts for interest rate and matching destroy rate.

In equilibrium, a worker / firm's strategy is to accept any match that weakly exceeds her expected present unmatched value: $S_{ij}(s|p) \geq 0$ if and only if $p \in A(s)$. Thus, the matching sets are

$$
\begin{aligned}
S_{AA}(s,p) &= f(s,p) - w_A(s) - w_A(p) \geq 0 \Leftrightarrow p \in \omega_{AA}(s) \Leftrightarrow s \in \omega_{AA}(p) \\
S_{AB}(s,p) &= f(s,p) - w_A(s) - w_B(p) - TC \geq 0 \Leftrightarrow p \in \omega_{AB}(s) \Leftrightarrow s \in \omega_{AB}(p)
\end{aligned}
\tag{11}
$$

Substituting (10) into (4), we obtain the value function of an unemployed worker of type s and the value function of an unmatched job p:

$$
\begin{aligned}
w_A(s) =& \mathrm{UB} + \max_{t_A(s)\in 0,1} \Big\{ t_A(s)\theta \frac{\mu L_A}{(r+\delta)} \int_{\omega_{AA}(s)} [f(s,p) - w_A(s) - w_A(p)]\upsilon_A(p)dp + \\
& [1-t_A(s)]\theta \frac{\psi\mu L_B}{(r+\delta)} \int_{\omega_{AB}(s)} [f(s,p) - w_A(s) - w_B(p) - TC]\upsilon_B(p)dp \Big\} \\
w_A(p) =& (1-\theta)\frac{\mu L_A}{(r+\delta)} \int_{\omega_{AA}(p)} [f(s,p) - w_A(s) - w_A(p)]t_A(s)u_A(s)ds + \\
& (1-\theta)\frac{\psi\mu L_B}{(r+\delta)} \int_{\omega_{BA}(p)} [f(s,p) - w_B(s) - w_A(p) - TC][1-t_B(s)]u_B(s)ds
\end{aligned}
\tag{12}
$$

In the first equation of (12), the second term on the right-hand side is the expected value of the worker's share of match surplus in region A and the third term is the expected value of the worker's share of match surplus in region B. Equation (12) implies that in equilibrium the expected surplus of matching is equal to the opportunity time cost of search.

A search equilibrium is characterized as a quadruple (w, V, ω, u), where w solves the value equation system (12) given (ω, u, υ); V sloves the free entry condition (7) given (ω, w, u), ω is matching set given w based on (11); and u solves the steady state equation (3) given (ω, υ).

It is impossible to solve the model analytically because the wage function $w(x)$ is not available[8]. Therefore, we have to solve the model numerically[9]. The results of this numerical

[8]Shimer and Smith (2000) have a proof of the existence of the equilibrium. Teulings and Gautier (2004) apply a second-order Taylor expansion to characterize the equilibrium.

[9]First, we divide the type space into 300 discrete types. Second, we guess initial values for all endogenous objects, and then take the following steps: (i) calculate the associated steady state unemployment rates using (3), calculate the value function using (12) and then calculate a new matching set using (11); (ii) repeat process

solution are presented in the next section.

2.4 Illustration of the Equilibrium

We assume that both the worker type s and firm type p follow log normal distribution on the interval [1, 4][10]. The other parameters in the model are set as follows: discount rate r is normalized to 1, exogenous destroy rate $\delta = 2r$, size of labor market $L_A = 10L_B = 5000r$, bargaining power of workers $\theta = 0.5$, commuting cost $TC = 0.4$, unemployment benefit UB $= 0.4$ and sunk entry cost $f_E = 1.8$.

In the frictionless matching model with complementarities, workers and jobs end up with the optimal match. When search is costly, we can no longer expect perfect assortative matching, because workers/firms will widen the set of partners that they will accept in order to save on search cost. In this section we firstly discuss the case without inter-regional job search, i.e., $\psi = 0$, and then analyze the results allowing for inter-regional job search with different efficiency indicator ψ (or different commuting costs TC) and different size of the large region.

2.4.1 No Inter-regional Job Search

The contact rate is higher in region A which suggests that workers and firms expect to have more contacts per unit of time. Because the expected value of continued search is higher in region A, workers and firms are more selective, indicating that the matching set is narrower in region A than that in region B. The first panel in Figure 2 illustrates the matching sets of workers and firms in both regions. The lighter shaded area denotes the matching set in region

(i) until the matching set does not change; (iii) calculate the expected firm profit using (7). If it is larger than the sunk entry cost of a vacancy, we increase the number of vacancy openings in the market and repeat (i), (ii) and (iii) until the expected value of vacancies converge to the sunk entry cost. The program is available upon request.

[10] We choose the mean 0.693 and standard deviation 0.27 to make sure that 95% of the values drawn from the log normal distribution lie in the range of [1, 4].

A and the whole (lighter and darker) shaded area is the matching set in region B. The upward sloping bands are a direct consequence of the equilibrium with positive assortative matching: the low types are rejected by the high types. And as shown in Figure 2(A), in equilibrium the interval of types that workers / firms are willing to match is remarkably larger in region B. The upper right panel shows the reservation wage of workers in region A and B, both of which are convex reflecting the nature of the production technology. The reservation wage is higher in the large region for every skill type since the expected value of search is higher, and the inter-regional reservation wage difference of the same worker type increases with skill levels [11]. It implies that high-skilled workers gain more from an improved match, which is crucial for the self-selection of high-skilled workers to the large region when inter-regional job search is allowed for. The bottom left panel presents the values of vacancies in region A and B. For the firms with low productivity, the expected value of a vacancy is higher in the small region since relatively high-skilled workers would also accept the matching due to the low contact rate. However, for the firms with high productivity, the expected value is higher in the large region because of the higher probability to contact with proper partners. The bottom right panel illustrates the unemployment rate by worker types in both regions. Low-skilled workers have a much higher unemployment rate since they are rejected by high productivity firms. The unemployment rate increases for the very high types because the high-skilled workers prefer not to match with low productivity firms in order to assure a good match. The unemployment rate is lower in the large region because of the higher contact rate. And the difference in inter-regional unemployment rates is smaller for high-skilled workers.

[11] This is the result of the production function with complementarities. If the production function is $f(s, p) = s + p$, an improved match is equally valuable for workers with different skills.

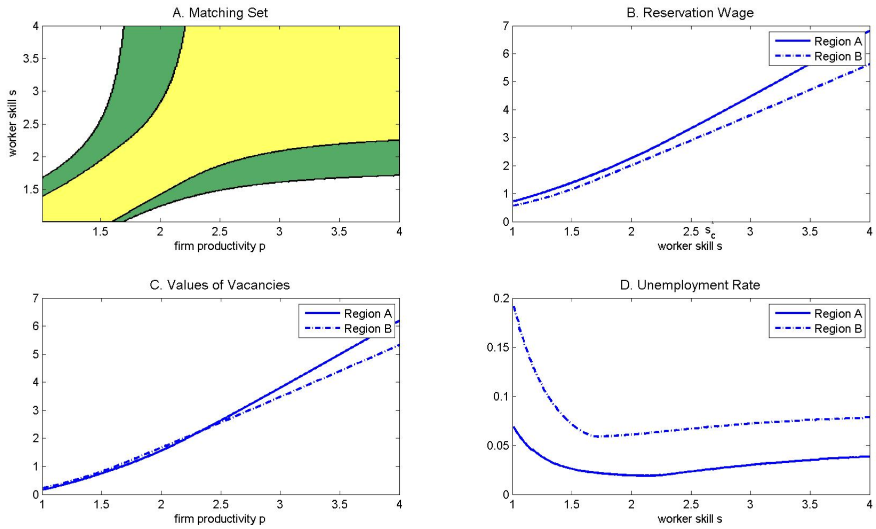

Figure 2: Equilibrium without inter-regional job Search $\psi = 0$

2.4.2 Inter-regional Job Search with Different Relative Search Efficiency

In this section, the inter-regional job search between region A and B is allowed for. Workers optimally allocate their unit time endowment by comparing the values of being unemployed when searching for jobs in two regions (see equation (5)). As search is more efficient in region A, only residents in region B have incentives to search jobs in region A. As the benefit of matching with firms of high productivity is greater for high-skilled workers than for low-skilled workers, moreover, inter-regional job search is less efficient than intra-regional job search ($\psi \leq 1$) and workers have to pay commuting costs when employment is found in other region, only high-skilled workers living in the small region find it profitable to search jobs in the large region and commute to work if they are employed. Nevertheless, low-skilled workers find that the increased value of being unemployed by searching jobs in the large region cannot compensate for the commuting cost. So low-skilled workers in the small region only search jobs locally. In particular, workers with skills above the cutoff level s_c^* (see Figure 3(B)) in

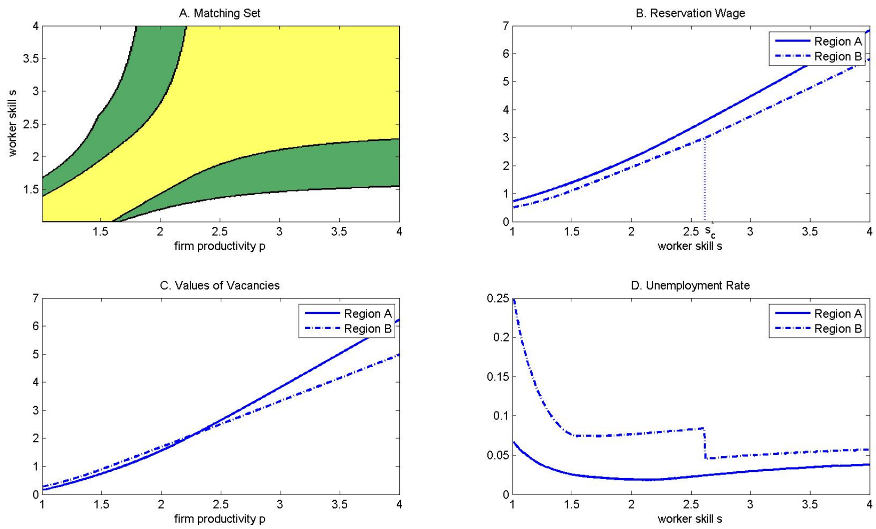

Figure 3: Equilibrium with inter-regional job Search $\psi = 0.4$

region B only search jobs in region A. However, workers with skills below the cutoff level in region B search for jobs locally. Since more high-skilled workers search for jobs in region A, firms, especially high productivity firms in region A become more selective in which way the strength of matching in region A is slightly improved. Because the remaining workers who search for jobs in the small region are low- and medium-skilled, firms widen the set of workers that they accept and thus the value of vacancies with high productivity decreases in the small region. The free entry condition implies that job (vacancy) openings decrease dramatically in the small region. Figure 4 shows that the vacancy density decreases in the small region when the inter-regional job search is allowed, while the vacancy density increases slightly in the large region because of the inflow of high-skilled workers from the small region. As shown in Figure 3(D), the unemployment rate of low-skilled workers in region B increases remarkably when inter-regional job search is allowed for. While the unemployment rate of high-skilled workers (above s_c^*) decreases in region B.

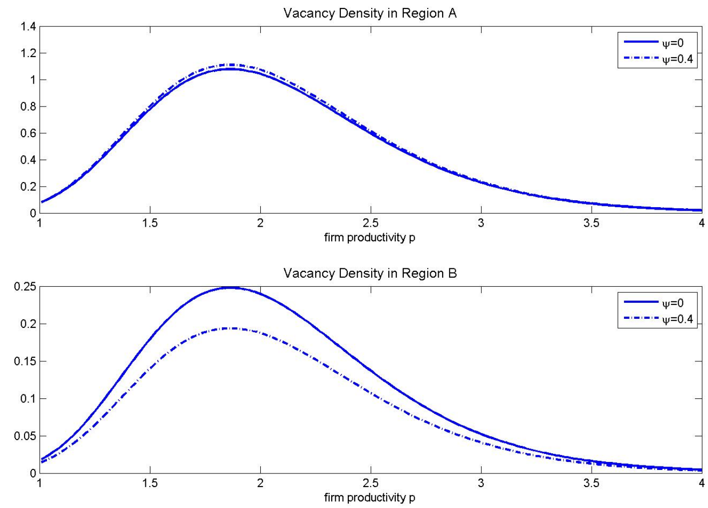

Figure 4: Vacancy Density in Region A and B

We change the inter-regional job search efficiency indicator ψ from 0.34 to 0.4 to see the change of matching set, reservation wage/vacancy value and unemployment rate in A and B, respectively[12]. Figure 5 illustrates the reservation wage in the small region for different inter-regional search efficiency indicators. When the inter-regional job search efficiency indicator increases from 0.34 to 0.4, the cutoff skill level for commuters shifts leftwards suggesting that more workers living in region B afford to search jobs in region A. High-skilled workers who are able to commute, benefit from the high contact rate in the large region and thus have higher reservation wage compared to the situation with lower inter-regional job search efficiency. However, the commuting of high-skilled workers from the small region to the large region leads to a drop in the vacancy openings in the small region which diminishes the local contact rate. Thus, the reservation wage of low-skilled workers decreases as the inter-regional job search efficiency increases (or the improvement of commuting technology).

The results suggest that when taking account of the spatial interactions between regional

[12]For example, government carries out some policies aiming to improve the inter-regional job search efficiency.

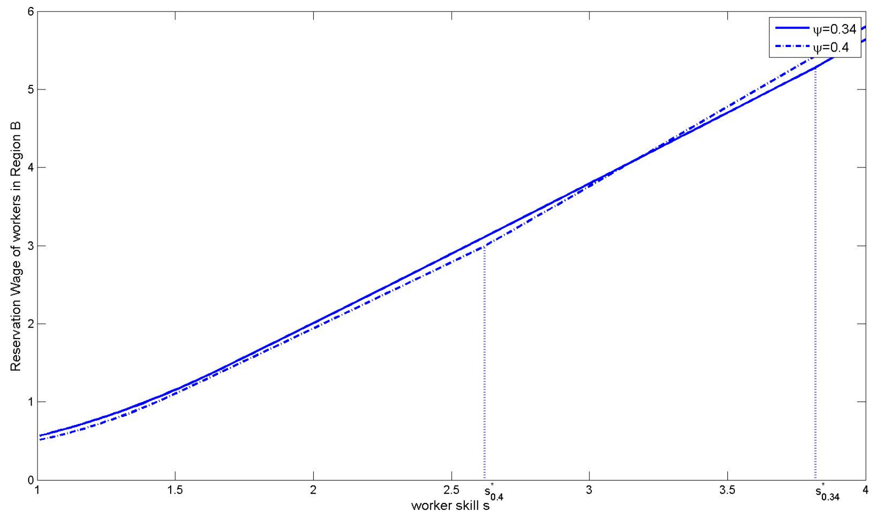

Figure 5: Reservation Wage in Region B for different inter-regional Search efficiency ψ

labor market the outcomes of regional labor market depends not only on the size of local labor market but also on the size of labor market in neighboring areas. If the inter-regional job search efficiency ψ and commuting costs TC depend on the distance between regions, high-skilled workers in the small region are better off by being close to the large market, however, low-skilled workers are worse off by being close to the large market.

2.4.3 Inter-regional Job Search with Different Size of the Large Region

In this section, we change the size of the large region. In particular, we increase the relative size of the large region from $L_A = 8L_B$ to $L_A = 10L_B$. Similarly, the cutoff skill level for commuters shifts leftwards suggesting that more workers in the small region commute if it has larger neighboring areas. High-skilled workers in region B have higher reservation wage if the relative size of region A increases. However, low-skilled workers have lower reservation wage if the relative size of the large region increases.

2.5 Extension: Worker Migration

Up to this point workers are exogenously domiciled in a given region but can commute between locations. In this section, we relax this assumption by allowing for the worker migration across regions, which endogenizes the regional skill distribution. Let us label workers by their initial residence in region i and denote the cost of moving from B to A by $C_m > 0$ (residents in region A have no incentive to move to region B since the reservation wage is higher for every skill type in region A than that in region B, which allows us to focus exclusively on the behavior of residents in region B). Migration cost C_m is assumed to be larger than the present value of commuting cost[13]. Particularly, C_m is set to be 0.8 in the simulation. Workers continue to migrate till the inter-regional gap of the value of being unemployed for s-type is equal to migration cost.

The migration equilibrium condition for residents in region B is:

$$W_A(s) - W_B(s) = C_m \tag{13}$$

That is, the incremental value of a mover net of migration cost must be zero in equilibrium. The upper right panel in Figure 6 illustrates the cutoffs for migration and commuting. Because the increase in the expected value from moving increases with worker types, only very high-skilled workers (above s_m^*) in region B migrate to region A. Medium-skilled workers (in the range of (s_c^*, s_m^*)) in region B only search jobs in region A and commute to work if employment is found. Low-skilled workers (below s_c^*) only search jobs in the small region.

Figure 7 shows the skill distribution in both regions. Region A has disproportionately

[13]Migration cost can be interpreted as the house prices gap between the big city and the small town. For simplicity, we assume this gap is exogenously given.

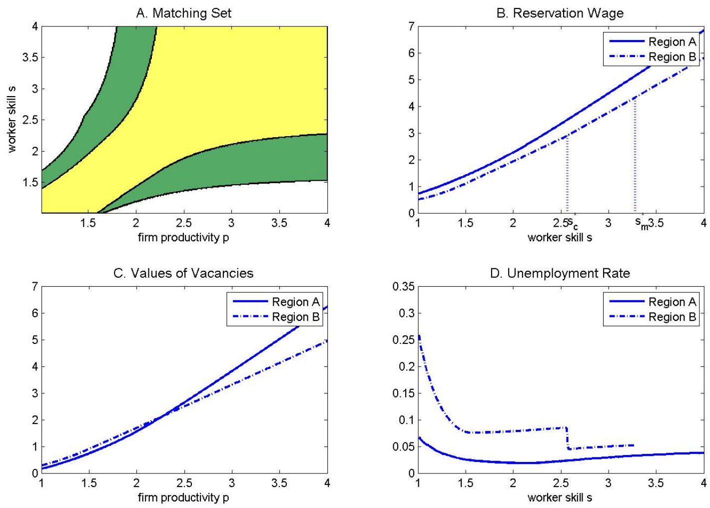

Figure 6: Equilibrium: Migration with $\psi = 0.4$

more high-skilled workers. This is consistent with the fact that workers with higher-skills tend to agglomerate in the larger, denser and more skilled labor market (Combes et al., 2008; Bacolod et al., 2008).

Our paper yields a number of testable implications for the commuting behavior, the strength of assortative matching across regions, and the regional skill distribution. Below, we summarize the model's main implications. Labor mobility costs, namely commuting cost, discounted inter-regional job search efficiency and migration cost, lead to a selection of high-skilled workers to big cities by either commuting or migration. Because of the outflow of high-skilled workers from the small towns to the large cities, job (vacancy) openings have a dramatic decrease in small towns. Consequently, workers and firms are less choosy which suggests that the strength of matching for remaining workers in small towns is deteriorated. So high-skilled workers in small towns benefit from being close to large cities, however, low-skilled workers in small towns suffer from being close to large cities. When migration is allowed, workers with sufficiently high skills migrate to large cities. The medium-skilled workers

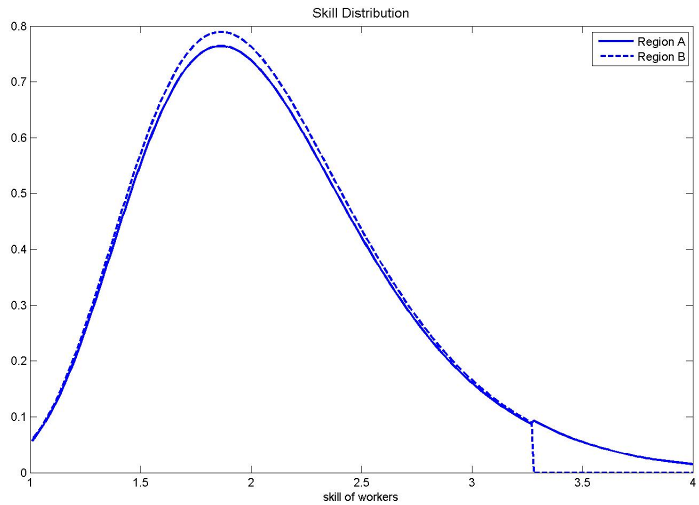

Figure 7: Skill distribution in Region A and B

only search jobs in large cities and commute if employment is found. Thus, large cities host disproportionately more high-skilled workers.

3 Data

3.1 Data Description

A unique Belgian linked employer-employee dataset (LEED) is used to test the main implications of the model. This dataset is collected by the Crossroads Bank for Social Security in Belgium, an organization specialized in combining data on Belgian workers from different administrative sources, such as the Belgian employment agencies and the National Social Security Office. The data covers nearly the whole Belgian population and initially consists of 35,721,027 observations, with each observation corresponding to a worker-firm-year combination. The dataset covers 11 years, ranging from 1998 to 2008. At the individual worker level the data provide information on age, gender, gross daily wage (full time equivalent), location of residence and workplace, labor market status, and an indicator of whether a worker is a full- or part-time worker. At the firm level, the data contains the information on firm location, number of employees, the industry in which the firm operates and an indicator of whether a firm is a single- or multi-plant firm. Firm's as well as worker's location are reported at the municipality level. Municipalities are the smallest administrative regions in Belgium of which there are a total of 589. This high level of geographical disaggregation in the data allows us to construct detailed measures of labor market size. One limitation of the data is that there are no direct links between workers and establishments, but only between workers and firms[14]. However, the single-plant indicator allows us to use only single-plant firms as a robustness check in this paper.

Since in Belgium the minimum mandatory schooling age is 18 and the official mandatory retirement age is 64, we remove workers with an age smaller than 18 or higher than 64 from the sample. In case a worker has multiple jobs at the same time, only the primary job (paying the highest wage) is kept. Workers with a wage below the 1st or above the 99th percentile of the wage distribution are dropped. Workers who earn less than a minimum wage are dropped. Workers working in public sectors, education and health sectors are dropped, because their wage is heavily regulated (See Appendix A for a detailed description of the dataset and cleaning process). Table 1 provides some summary statistics for the sample.

3.2 Some Stylized Facts

Regions differ in the size of labor market and thus the efficiency of job search, which lead to wage disparities across regions. Figure 8 shows a clear positive relationship between a region's average wage and its size, measured in terms of working population. This confirms

[14] The dataset only provide worker-establishment information in 2007 and 2008.

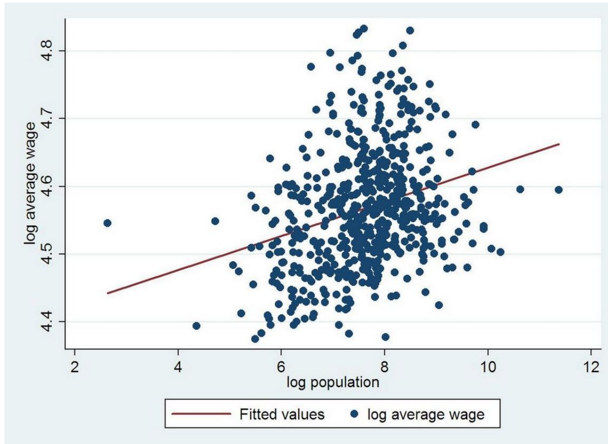

Figure 8: Average Wage and Size of Labor Market (2000)(slope=0.025, s.e.=0.0034)

the commonly reported stylized facts that the average wage is higher in large cities.

The spatial interactions between regional labor markets are intensive in Belgium. Figure 9 shows the average commuting rate and migration rate at municipality level. A commuter is defined as a worker who works in a municipality which is different from the one where she lives. The average commuting rate is calculated as the ratio of the total number of commuters over the total number of workers. A migrant refers to a worker who changes her place of residence across time period. The average migration rate is the ratio of the total number of migrants over the total number of workers. The average commuting rate stably increased from 80.31% to 81.68% in Belgium during the period 1998-2008. In contrast, the average migration rate in Belgium is rather low, around 6.0%. So we mainly focus on the commuting behavior in Belgium in the remainder of the paper.

The model implies that high-skilled workers are more likely to commute to large cities. Figure 10 provides strong evidence for it. The average commuting rate is higher for workers with higher skills measured by their average wage. The average commuting rate is 67% for workers with the average wage below the 10th percentile while it is up to 90% for workers

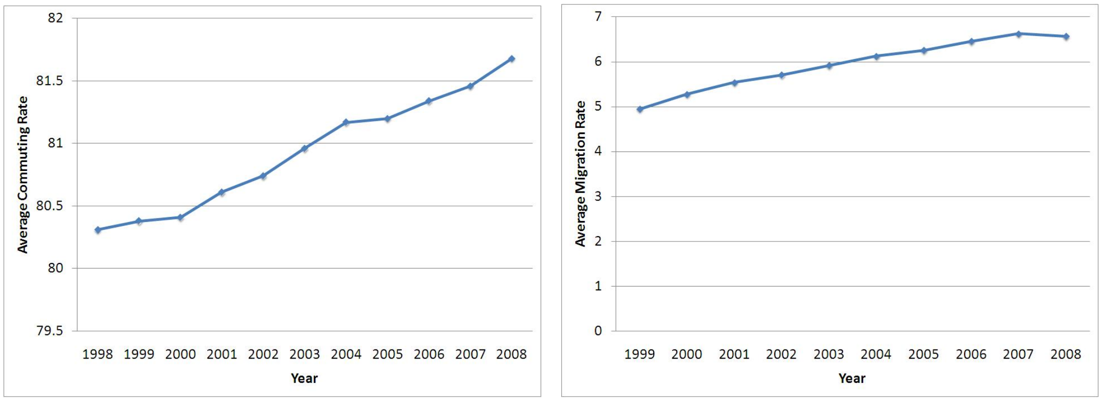

Figure 9: Average Commuting Rate and Migration Rate in Belgium

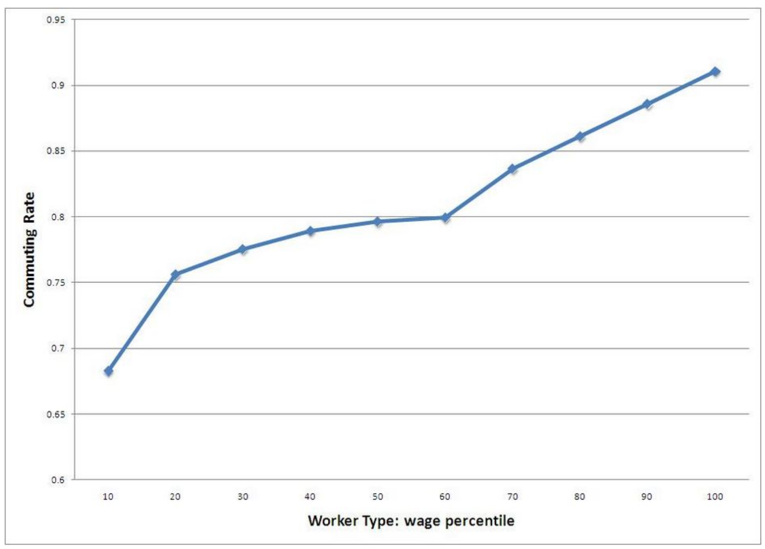

Figure 10: Commuting Rate and Worker Types

above 90th percentile of average wage distribution.

4 Empirical Strategy

4.1 Measuring the Strength of Matching

In order to construct the strength of matching, we need to measure the quality of workers and firms. The most commonly used methodology applied to a linked employer-employee data is the linear wage decomposition proposed by Abowd et al. (1999)(AKM henceforth).

$$logw_{it} = x_{it}\beta + \theta_i + \psi_{J(i,t)} + \epsilon_{it} \tag{14}$$

where w_{it} denotes the wage of worker i at time t, x_{it} are time-varying observed characteristics of worker i, θ_i is a worker fixed effect, $\psi_{J(i,t)}$ is a firm fixed effect and ϵ_{it} is a residual and is assumed to be orthogonal to the explanatory variables in equation (14). The parameters β, θ_i and ψ_j are estimated using the iterative conjugate gradient algorithm described in Abowd et al. (2002). The correlation between worker and firm effect $Corr(\widehat{\theta}, \widehat{\psi})$ measures the strength of matching. Using AKM method, several empirical studies find an insignificant or even negative correlation in fixed effects between worker and firm types in France, US, Denmark and Brazil. The results suggest that there is little sorting in labor market. However, Eeckhout and Kircher (2011) and Lopes de Melo (2009) argue that because of the non-monotonic effect of firm productivity on wages, an identification strategy based on AKM wage fixed effects model fails to identify sorting[15].

Instead, we apply a simple, alternative measure of worker and firm quality described in Lopes de Melo (2009). Since higher type workers in searching model obtain higher wages on average, the average wage of a worker $S_i = \frac{\sum_{t \in T_i} w_{it}}{T_i}$ recovers the true type of the worker, where T_i is the set of years that worker i shows in the data. Firm types are measured based on the quality of workers firm j hires, either the average worker type employed in firm j, i.e., $P_j = \frac{\sum_{t \in T_j} \sum_{i \in N_{jt}} S_i}{\sum_{t \in T_j} N_{jt}}$ or the best worker type employed in firm j, i.e., $P_j = \max_{t \in T_j, i \in N_{jt}}(S_i)$,

[15]Lopes de Melo (2009) proposes an alternative measure of match quality based on the correlation between a worker fixed effect and the average fixed effect of her coworkers. Using this measure, Lopes de Melo (2009) and Bagger and Lentz (2008) find that the correlation is between 0.3 and 0.4, suggesting that sorting plays an important role in labor market. Eeckhout and Kircher (2011) suggest that the wage dispersion for similar workers is informative about the degree of matching.

where N_{jt} is the set of workers employed in firm j at time t, T_j is the set of years that firm j shows in the dataset. The rank correlation between S_i and P_j, $Corr(S_i, P_j)$, measures the strength of sorting. This measure overestimates the degree of sorting in the economy because of the rent-sharing between firms and workers. However, as the number of years goes to infinity it converges to the true sorting correlation. If this upward bias is not affected by the size of labor market, we obtain the correct difference in match quality across regions of different size. In the empirical analysis, the strength of sorting is constructed using firms with at least 3 employees.

4.2 Empirical Specification

The match quality depends not only on the size of the local labor market but also on the size of the labor market in neighboring areas. The large local labor market improves the quality of match for both low- and high-skilled workers. Large neighboring area improves the match quality for high-skilled workers, however, it diminishes the quality of match for low-skilled workers. To examine the above theoretical implications, we use the following specifications:

$$Corr_{i\in r}(S_i, P_j)_H = \alpha_0 + \alpha_1 ln(\text{pop}) + \alpha_2 ln(\text{pop of neighboring areas}) + \gamma X + \epsilon_{rH} \tag{15}$$

$$Corr_{i\in r}(S_i, P_j)_L = \beta_0 + \beta_1 ln(\text{pop}) + \beta_2 ln(\text{pop of neighboring areas}) + \gamma X + \epsilon_{rL} \tag{16}$$

where $Corr_{i\in r}(S_i, P_j)_H$ denotes the rank correlation (match quality) between types of high-skilled workers and the corresponding firm types. $Corr_{i\in r}(S_i, P_j)_L$ is the match quality for low-skilled workers. High-skilled workers are defined as the workers above the 75th percentile of skill distribution, i.e., an average wage larger than 121.50 Euro. Low-skilled workers are the workers below the 25th percentile of skill distribution, i.e., an average wage lower than 81.74 Euro. ln(pop) is the log population of local municipality, while ln(pop of neighboring areas) is the log population of neighboring areas. α_1, α_2, β_1, and β_2 are the coefficients of interest. X refers to a vector of control variables, for example, average firm size, average house price etc.

Neighboring areas are constructed in terms of distance and commuting time. By mapping NIS-code with geographic coordinates (latitude and longitude), we are able to calculate the straight-line distances between each NIS-code and construct circles of radius r around the geographic centroid of each NIS-code. Population of local region is defined as the number of workers living in the local municipality. In the dataset, 73.76% workers commute within a 50km radius around the location of residence. So the population of neighboring areas is defined as the number of workers living within a 50km radius around the municipality of residence (exclude the population of own municipality). We also construct neighboring areas based on travel time of commuting (by car or by train), for example, regions that can be reached via auto-highway within 60 minutes[16].

We rely on OLS results to test the implications of the model. On one hand, the population at municipality level in Belgium is not likely to change substantially over time. On the other hand, the number of firms in a region does not response to the change in the population immediately.

[16]In the dataset, 84.79% workers commute to regions that can be reached via auto-highway within 60 minutes from the municipality of residence.

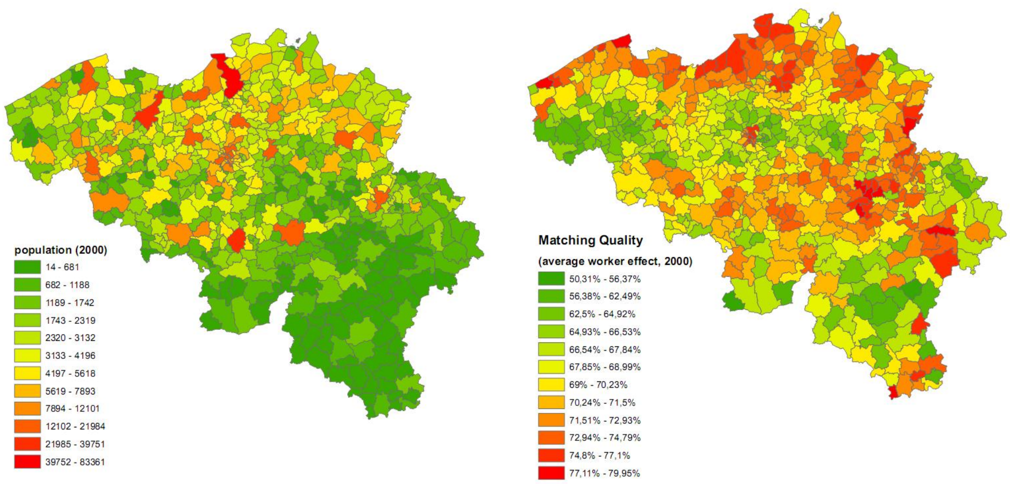

Figure 11: Population and Match Quality at Municipality level (2000)

5 Results

To get some feel for the spatial structure, maps of Belgium are shown in Figure 11. Particularly, Figure 11 shows considerable spatial variation in labor market size and match quality. The darkest areas reflect the densest labor market or the highest match quality.

5.1 Commuting Rate, Number of Firms and Size of Labor market

First, we show some scatter plots to illustrate the basic intuitions of our model. The model predicts that, ceteris paribus, workers living in small regions are more likely to commute to other regions for the high job search efficiency, moreover, the commuting rate is higher for regions which have denser neighboring areas. The two scatter plots in Figure 12 show a negative correlation between the commuting rate and the log population of local region and a positive correlation between the commuting rate and the log population of neighboring areas[17].

[17] Commuting rate is defined as the ratio of the number of commuters (whose place of work is different from her place of residence) to the total number of workers at municipality level.

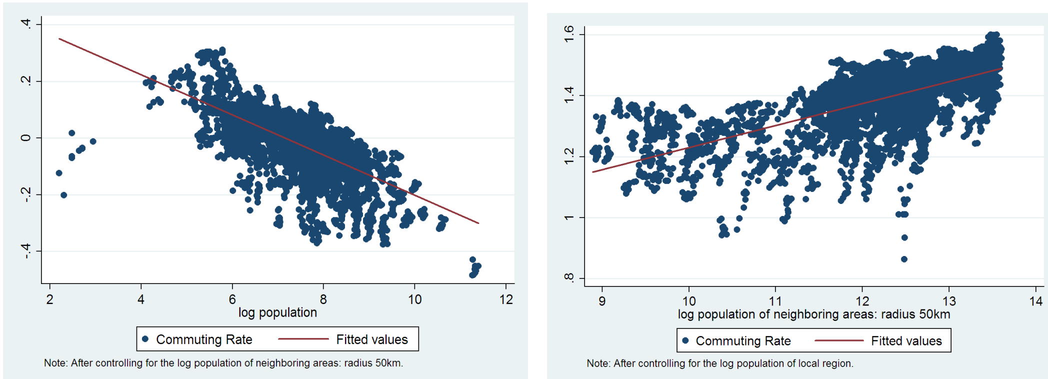

Figure 12: Commuting Rate and Size of Labor Market A. Log Population of Local Market (slope=-0.071, s.e.=0.002) B. Log Population of Neighboring Areas (slope=0.072, s.e.=0.0017).

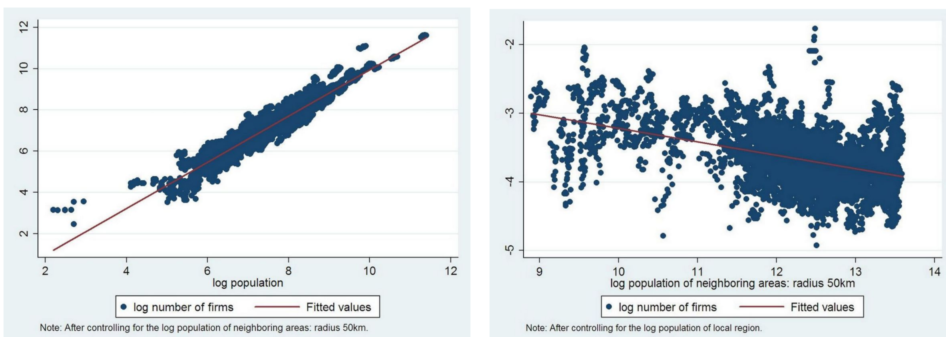

Figure 13: Number of Firms and Size of Labor Market A. Log Population of Local Market (slope=1.12, s.e.=0.0087) B. Log Population of Neighboring Areas (slope=-0.20, s.e.=0.0072).

Turning to the number of firms and the size of labor market, the left panel of Figure 13 indicates that the log number of firms at municipality level is strongly positively correlated with the log population of local region. However, the right panel of Figure 13 suggests that, other things being equal, the number of firms is smaller for regions which have denser neighboring areas.

Figure 12 and 13 provide us a general picture of the intuition underlying the model in Section 2. Workers living in a region being close to dense neighboring areas are more likely to commute, which leads to a decrease in the job openings in the local region.

5.2 Match Quality and Size of Labor Market

We measure skill and productivity with wage data. The rank correlation between skill and productivity measures the match quality. The average match quality for high-skilled workers is 0.24, while the average match quality for low-skilled workers is 0.44[18]. Firm types can be measured by the average worker type it hires or the best worker type it hires. We report the results using these two measures in Table 2 and 3, respectively. The first four columns in Table 2 show the results for high-skilled workers. The impact of the size of neighboring areas on the match quality for high-skilled workers is larger than the impact of the size of local market. In particular, the size of neighboring areas has a significantly positive effect on the match quality of high-skilled workers. However, the coefficient of the size of local market is small and insignificant. The results in column (3) and (4) show that the estimates of the coefficient of log population of neighboring areas are not much affected by the inclusion of the additional controls. The last four columns in Table 2 shows the results for low-skilled workers, suggesting that the impacts of the size of local region and the size of neighboring areas are of comparable magnitude. The size of local market has a significantly positive effect on the match quality of low-skilled workers while the size of neighboring areas has a significantly negative effect on the match quality of low-skilled workers. Interestingly, the match quality of high-skilled workers is significantly lower in regions along the language border, as the language border inhabits high-skilled workers from benefiting from dense neighboring areas, whereas, the match quality of low-skilled workers is not significantly affected by the language border. The results in Table 3 show that the main results do not change by using an alternative measure of firm types, that is the best worker type a firm hires.

[18] Firm types are measured by the average worker type a firm hires.

Table 4 presents the results of two robustness checks. Brussels, which hosts the headquarters of the European Union, is the largest urban area in Belgium. The results reported in Table 2 and 3 may be driven by Brussels-effect. As a robustness check, we present the results in Table 4 excluding 19 municipalities in the Brussels-Capital region in the dataset. The results are robust to excluding Brussels-Capital region.

We only have matched worker-firm data, in which we are not able to identify the direct links between workers and establishments. In the dataset, around 3% firms are multi-plant firms, employing about 1/3 of employees. In order to capture the direct links between workers and establishments, we use the subsample of workers working in single-plant firms to construct rank correlations. The last four columns in Table 4 show the results and the results do not change.

We also measure the size of labor market by density. The results are presented in Table 6 in Appendix C, suggesting that the main results hold. In Appendix D, we present the results using alternative measures of neighboring areas which are constructed in terms of commuting time. The results using neighboring areas based on the travel time of commuting by car are consistent with the implications of our model, whereas the results using neighboring areas based on the travel time of commuting by train show that the coefficient of the size of neighboring areas is positive but insignificant for high-skilled workers. One possible reason would be that high-skilled workers are likely to commute by car and thus their commuting destination areas are not restricted to the availability of trains between two municipalities.

6 Conclusion

We have proposed a model with a continuum of job and worker types, complementarities in production, search frictions and free entry, allowing for inter-regional labor mobility. The interaction of increasing returns to scale in job search and labor mobility costs gives rise to a series of new features. The large labor market improves the quality of the match between firms and workers. Because of the presence of labor mobility costs, only high-skilled workers are able to migrate or commute to the large cities, whereas low-skilled workers continue to search jobs in the local region. The outflow of high-skilled workers leads to a decease in the job openings in the local region. Our model shows the above self selection mechanism. It further shows that high-skilled workers in a region benefit from being close to dense neighboring areas, since they are able to benefit from the scale effect from the neighboring areas which leads to an increase in the strength of assortative matching. However, because of the decline in job openings in the local region, left-behind low-skilled workers suffer from being close to dense neighboring areas. Our results suggest that a policy which aims to increase inter-regional job search efficiency or decrease labor mobility costs, for example, provide subsidies to commuters, may harm low-skilled workers in small towns.

We find empirical support for our theory using a unique Belgian linked employer-employee dataset. Our measures of skill and productivity derive directly from wages which incorporate unobservable characteristics of skill and productivity. High-skilled workers are more likely to commute. Regions which have denser neighboring areas host less firms. The large local labor market improves the quality of match for all worker types, especially for low-skilled workers. Large neighboring area improves the match quality of high-skilled workers, however, it diminishes the match quality of low-skilled workers.

A Data Cleaning Process

We start with 35,721,027 observations, each observation corresponds to a worker-firm-year cell.

All observations with a wage below the 1st percentile or above the 99th percentile of the wage distribution are dropped. This leaves us with 34,655,478 observations.

Workers who earn less than a minimum wage (The monthly gross statutory minimum wage is 1186.31 Euro in Belgium in 2004, which is equivalent to 54 Euro of gross daily wage) are dropped. This leaves us with 33,894,307 observations.

We restrict the sample to private sectors. The sectors are defined based on the NACE 2003 classification, so firms operating in a 2-digit NACE sector above 74 are dropped. This leaves us with 20,390,188 observations. We also discard observations living in the neighboring countries, for instance, Netherlands and France. This procedure yields 20,126,230 observations.

B Percentiles of Average Wage Distribution

C Population or Density

D Different Measures of Neighboring Areas

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Table 1: Summary Statistics

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Observations	1,736,435	1,771,767	1,833,817	1,855,065	1,838,201	1,816,125	1,834,323	1,847,400	1,881,983	1,926,683	1,784,431
Daily wage	94.76	96.47	99.90	103.21	105.08	106.46	108.74	111.95	114.20	115.49	121.80
Age	37.07	37.15	37.14	37.38	37.70	38.03	38.20	38.40	38.54	38.65	38.93
Male(%)	70.49	69.68	68.76	67.93	67.46	67.14	66.61	66.13	65.60	64.87	66.89
Population	2932.05	3008.09	3113.44	3149.52	3120.89	3083.40	3114.30	3136.50	3195.22	3271.11	3029.59
Average firm size	14.57	14.35	14.31	14.20	13.87	13.58	13.56	13.57	13.72	14.03	13.93
Multi-plant firms(%)	2.84	2.81	2.70	2.70	2.64	2.66	3.15	3.32	3.39	3.39	3.44
No. of firms	120,259	125,080	129,888	132,432	134,257	135,481	137,103	138,000	139,148	139,442	134,679

Note: Daily wage is full-time equivalent gross daily wage, expressed in Euro. Population is defined as the average number of working population at municipality level. The sample is restricted to workers aged 18-64. *Source:* Author's calculation.

Table 2: Match Quality

	High-skilled Workers				Low-skilled Workers			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	RE	OLS	RE	OLS	RE	OLS	RE
Log(pop)	-0.0014	-0.0041	0.000062	-0.00022	0.012***	0.012***	0.013***	0.013***
	(0.0016)	(0.0047)	(0.0019)	(0.0044)	(0.0011)	(0.0025)	(0.0013)	(0.0028)
Log(pop of neighboring areas)	0.0083***	0.0093**	0.011***	0.010**	-0.014***	-0.015***	-0.0091***	-0.013***
	(0.0016)	(0.0046)	(0.0023)	(0.0047)	(0.0012)	(0.0027)	(0.0015)	(0.0032)
Language border dummy			-0.031***	-0.032***			-0.00089	-0.0013
			(0.0029)	(0.0082)			(0.0025)	(0.0060)
Average firm size			-0.00037***	-0.00081***			-0.00092***	-0.00050**
			(0.00013)	(0.00030)			(0.00011)	(0.00022)
Average age of workers			0.0070***	0.0078**			-0.0074***	-0.0031
			(0.0016)	(0.0034)			(0.0011)	(0.0025)
Log(house price)			-0.021**	-0.0063			-0.0020	0.0065
			(0.0088)	(0.0058)			(0.0038)	(0.0056)
Job switch rate			0.22**	0.053			-0.25***	-0.100**
			(0.095)	(0.052)			(0.059)	(0.048)
Year fixed effect	yes	yes	yes	yes	yes	yes	yes	yes
Observations	6,468	6,468	5,879	5,879	6,468	6,468	5,879	5,879
R-squared	0.015	0.014	0.04	0.034	0.20	0.20	0.15	0.14

Note: Unit is municipality. The dependent variable is match quality measured by the rank correlation between worker and firm types. Robust standard errors are in parentheses. *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. House price is measured by the weighted average price of house, villa, apartment and lot. Herstappe, the least populous municipality in Belgium, is dropped.

Table 3: Match Quality: Alternative Measure of Firm Types

	High-skilled Workers				Low-skilled Workers			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	RE	OLS	RE	OLS	RE	OLS	RE
Log(pop)	-0.0085***	-0.0098**	-0.015***	-0.012**	0.0064***	0.0094***	0.0081***	0.010***
	(0.0016)	(0.0047)	(0.0020)	(0.0049)	(0.0013)	(0.0030)	(0.0014)	(0.0032)
Log(pop of neighboring areas)	0.014***	0.016***	0.014***	0.019***	-0.014***	-0.016***	-0.014***	-0.016***
	(0.0018)	(0.0058)	(0.0025)	(0.0059)	(0.0014)	(0.0033)	(0.0017)	(0.0037)
Language border dummy			-0.016***	-0.018**			0.0062**	0.0076
			(0.0028)	(0.0082)			(0.0030)	(0.0071)
Average firm size			0.00055***	0.00018			-0.00019*	-0.00027
			(0.00014)	(0.00030)			(0.00011)	(0.00026)
Average age of workers			-0.011***	-0.0024			0.0043***	0.0010
			(0.0017)	(0.0037)			(0.0012)	(0.0029)
Log(house price)			0.010	-0.00025			0.0063**	0.0064
			(0.011)	(0.0046)			(0.0031)	(0.0043)
Job switch rate			0.29***	-0.096			-0.22***	-0.10*
			(0.10)	(0.091)			(0.068)	(0.051)
Year fixed effect	yes	yes	yes	yes	yes	yes	yes	yes
Observations	6468	6468	5879	5879	6468	6468	5879	5879
R-squared	0.016	0.016	0.037	0.023	0.071	0.070	0.056	0.052

Note: Unit is municipality. The dependent variable is match quality measured by the rank correlation between worker and firm types. Robust standard errors are in parentheses. *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. House price is measured by the weighted average price of house, villa, apartment and lot. Herstappe, the least populous municipality in Belgium, is dropped.

Table 4: Robustness Checks

	Exclude Brussels				Single-plant Firms			
	High-skilled Workers		Low-skilled Workers		High-skilled Workers		Low-skilled Workers	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	RE	OLS	RE	OLS	RE	OLS	RE
ln(pop)	0.00086	-0.00027	0.012***	0.013***	-0.0020	-0.0038	0.012***	0.014***
	(0.0020)	(0.0045)	(0.0013)	(0.0028)	(0.0028)	(0.0065)	(0.0018)	(0.0038)
ln(pop of neighboring areas)	0.011***	0.0100**	-0.0069***	-0.011***	0.030***	0.033***	-0.0053**	-0.011***
	(0.0023)	(0.0048)	(0.0015)	(0.0032)	(0.0030)	(0.0057)	(0.0022)	(0.0041)
language border dummy	-0.031***	-0.032***	-0.0030	-0.0036	-0.025***	-0.024**	-0.0060*	-0.0066
	(0.0029)	(0.0082)	(0.0025)	(0.0060)	(0.0037)	(0.0094)	(0.0034)	(0.0082)
average firm size	-0.00068***	-0.00096***	-0.00033***	-0.00021	-0.00063***	-0.0010***	-0.0011***	-0.00073**
	(0.00018)	(0.00036)	(0.00012)	(0.00027)	(0.00018)	(0.00040)	(0.00014)	(0.00031)
average age of workers	0.0090***	0.0087**	-0.011***	-0.0066***	0.018***	0.0088*	-0.0054***	-0.00064
	(0.0018)	(0.0037)	(0.0011)	(0.0025)	(0.0022)	(0.0049)	(0.0015)	(0.0033)
ln(house price)	-0.023**	-0.0062	0.0011	0.0077	-0.0075	0.0030	-0.016**	0.0019
	(0.0090)	(0.0059)	(0.0035)	(0.0057)	(0.013)	(0.0073)	(0.0065)	(0.0060)
job switch rate	0.23**	0.059	-0.27***	-0.12**	0.40***	0.038	-0.21**	-0.12
	(0.096)	(0.053)	(0.060)	(0.049)	(0.11)	(0.11)	(0.095)	(0.094)
year fixed effect	yes	yes	yes	yes	yes	yes	yes	yes
Observations	5689	5689	5689	5689	5879	5879	5879	5879
R-squared	0.043	0.037	0.16	0.15	0.099	0.093	0.091	0.083

Note: Unit is municipality. The dependent variable is match quality measured by the rank correlation between worker and firm types. Robust standard errors are in parentheses. *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. Housing price is measured by the weighted average price of house, villa, apartment and lot. Herstappe, the least populous municipality in Belgium, is dropped.

Table 5: Percentiles of Average Wage Distribution

Percentile	Worker Effect
10	70.86
20	78.17
30	85.09
40	91.44
50	97.37
60	104.34
70	114.59
80	129.86
90	157.60

Note: Worker effect is measured by the average full time equivalent gross daily wage of workers. *Source:* Author's calculation.

Table 6: Population or Density?

	Average Worker Type				Best Worker Type			
	High-skilled Workers		Low-skilled Workers		High-skilled Workers		Low-skilled Workers	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	RE	OLS	RE	OLS	RE	OLS	RE
ln(emp./sq.km.)	-0.0060***	-0.0047	0.0028**	0.0024	-0.0096***	-0.0096**	0.0030**	0.0056**
	(0.0013)	(0.0037)	(0.0011)	(0.0028)	(0.0014)	(0.0039)	(0.0012)	(0.0028)
ln(emp./sq.km. in neighboring areas)	0.016***	0.015**	-0.0037*	-0.0081*	0.021***	0.027***	-0.017***	-0.019***
	(0.0032)	(0.0074)	(0.0021)	(0.0044)	(0.0034)	(0.0085)	(0.0023)	(0.0049)
language border dummy	-0.032***	-0.032***	-0.0034	-0.0047	-0.015***	-0.018**	0.0050	0.0065
	(0.0029)	(0.0083)	(0.0025)	(0.0061)	(0.0029)	(0.0082)	(0.0030)	(0.0072)
average firm size	0.000018	-0.00068**	-0.00071***	-0.00031	0.00051***	0.00017	-0.000064	-0.00020
	(0.00015)	(0.00031)	(0.00012)	(0.00024)	(0.00015)	(0.00030)	(0.00012)	(0.00028)
average age of workers	0.0082***	0.0080**	-0.0097***	-0.0046*	-0.0076***	-0.0016	0.0020*	-0.00033
	(0.0015)	(0.0034)	(0.0011)	(0.0025)	(0.0017)	(0.0036)	(0.0012)	(0.0028)
ln(house price)	-0.019**	-0.0062	-0.0013	0.0067	0.0053	-0.00045	0.010***	0.0069
	(0.0092)	(0.0058)	(0.0040)	(0.0057)	(0.011)	(0.0046)	(0.0034)	(0.0044)
job switch rate	0.30***	0.058	-0.28***	-0.10**	0.25**	-0.099	-0.19***	-0.095*
	(0.095)	(0.052)	(0.059)	(0.047)	(0.11)	(0.091)	(0.068)	(0.051)
year fixed effect	yes	yes	yes	yes	yes	yes	yes	yes
Observations	5879	5879	5879	5879	5879	5879	5879	5879
R-squared	0.039	0.032	0.13	0.12	0.032	0.024	0.054	0.051

Note: Unit is municipality. The dependent variable is match quality measured by the rank correlation between worker and firm types. Robust standard errors are in parentheses. *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. House price is measured by the weighted average price of house, villa, apartment and lot. Herstappe, the least populous municipality in Belgium, is dropped.

Table 7: Robustness: Different Measures of Neighboring Areas

	120 Min by Train				60 Min by Car			
	High-skilled Workers		Low-skilled Workers		High-skilled Workers		Low-skilled Workers	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	RE	OLS	RE	OLS	RE	OLS	RE
Log(pop)	0.0038*	0.0033	0.014***	0.015***	0.00036	0.00021	0.012***	0.012***
	(0.0022)	(0.0052)	(0.0014)	(0.0032)	(0.0020)	(0.0046)	(0.0013)	(0.0028)
Log(pop of neighboring areas)	0.0012	0.0030	-0.0072***	-0.012***	0.0088***	0.0090*	-0.0073***	-0.012***
	(0.0021)	(0.0049)	(0.0014)	(0.0030)	(0.0023)	(0.0051)	(0.0015)	(0.0031)
Language border dummy	-0.028***	-0.029***	-0.0010	-0.0015	-0.031***	-0.032***	-0.00088	-0.0013
	(0.0029)	(0.0082)	(0.0026)	(0.0063)	(0.0029)	(0.0082)	(0.0025)	(0.0061)
Average firm size	-0.00030**	-0.00080***	-0.00095***	-0.00052**	-0.00030**	-0.00079***	-0.00098***	-0.00055**
	(0.00013)	(0.00030)	(0.00011)	(0.00022)	(0.00013)	(0.00030)	(0.00011)	(0.00022)
Average age of workers	0.0085***	0.0082**	-0.0077***	-0.0032	0.0076***	0.0080**	-0.0078***	-0.0035
	(0.0016)	(0.0034)	(0.0011)	(0.0025)	(0.0016)	(0.0034)	(0.0011)	(0.0025)
Log(house price)	-0.016*	-0.0060	-0.0028	0.0064	-0.020**	-0.0062	-0.0033	0.0062
	(0.0089)	(0.0057)	(0.0040)	(0.0057)	(0.0088)	(0.0058)	(0.0039)	(0.0056)
Job switch rate	0.38***	0.062	-0.31***	-0.11**	0.26***	0.055	-0.29***	-0.11**
	(0.091)	(0.052)	(0.058)	(0.047)	(0.094)	(0.052)	(0.059)	(0.048)
Year fixed effect	yes	yes	yes	yes	yes	yes	yes	yes
Observations	5689	5689	5689	5689	5879	5879	5879	5879
R-squared	0.033	0.026	0.15	0.14	0.038	0.032	0.15	0.14

Note: Unit is municipality. The dependent variable is match quality measured by the rank correlation between worker and firm types. Robust standard errors are in parentheses. *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. House price is measured by the weighted average price of house, villa, apartment and lot. Herstappe, the least populous municipality in Belgium, is dropped. The neighboring areas in the first four columns are the regions which can be reached via railway within 120 minutes from the region of residence. The neighboring areas in the last four columns are the regions which can be reached via auto-highway within 60 minutes from the region of residence.